# BEHAVIOUR OF RING FOOTING OVER REINFORCED SAND

***Project Report Submitted in fulfillment of the requirements for the degree of***

**Bachelor of Technology**

*in*

**Civil Engineering**

*by*

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# CERTIFICATE

This is to certify that the project entitled ***BEHAVIOUR OF RING FOOTING OVER REINFORCED SAND*** submitted by Mr. ***Rahul Agrawal*** (Roll No. **109CE0434**) in fulfillment of the requirements for the award of Bachelor of Technology Degree in Civil Engineering at NIT Rourkela is an authentic work carried out by them under my supervision and guidance.

Date: 13-5-2013
Place: Rourkela

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*Rahul Agrawal*

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# ABSTRACT

The main objective of my study is to investigate the use of geo-synthetics in geotechnical characteristics of sand and to evaluate the effects of geo-synthetics on shear strength of sand by carrying out direct shear tests and to evaluate the increase in the bearing capacity of sand by the application of footing load tests over sand at different relative densities. The experiments performed to evaluate the change in bearing capacity of sand after reinforcement show that there is an increase in bearing capacity of sand on reinforcement .This increase in bearing capacity increases with reinforcement provided upto a depth of B from the top layer of sand and then the increase gradually reduces at a depth of 1.5B and 2B from the top layer of the sand .

# CHAPTER – 1

# INTRODUCTION

For any land-based structure, the foundation is very important and has to be strong to support the entire structure. For the foundation to be strong, the soil around it plays a very critical role. We need to have a proper knowledge about their general properties like its' specific gravity ,maximum and minimum void ratio and dry density .

From the beginning of construction work, the necessity of enhancing soil properties has come to the light. Ancient civilizations of the Chinese, Romans and Incas utilized various methods to improve soil strength etc., some of these methods were so effective that their buildings and roads still exist.

An appropriate method to prevent sand failure or excessive settlement under loads is reinforcing the sand with geosynthetics, geotextiles,etc. The bearing capacity of foundations besides the parameters and conditions of the sand below the foundation depends on the shape of the foundation. Ring footing are usually used for symmetrical buildings like silos ,chimneys and oil storages. This study presents a series of laboratory studies on behaviour of ring footings over sand reinforced with geosynthetics.

# CHAPTER- 2

# LITERATURE REVIEW

## 2.1 Sand Reinforcement

### 2.1.1 Definition

Sand reinforcement is the process of altering some sand properties by different methods, mechanical or chemical in order to produce an improved sand material which has all the desired engineering properties.

Sands are generally stabilized to increase their strength and bearing capacity to resist failure due to excessive loading. The main aim is the creation of a sand material or system that will hold under the design use conditions and for the designed life of the engineering project. The properties of sand can be improved through compaction and reinforcement of sand layers at different depths. Various methods are employed to reinforce sand and the method should be verified in the lab with the sand material before applying it on the field.

Principles of Sand Reinforcement

- Evaluating the sand properties of the area under consideration.
- Deciding the property of sand which needs to be altered or improved inorder to achieve an improved sand with improved bearing capacity so as to be able to resist greater shear stress over it and choose the effective and economical method for reinforcement.
- Designing the reinforced sand sample and testing it in the lab for intended Values of bearing capacity.

### 2.1.2 Needs & Advantages

Construction of structures depends a lot on the bearing capacity of the sand, hence, we need to reinforce the sand with geosynthetics to improve the load bearing capacity.

Reinforced sand is a very cost-effective technique compared to other construction techniques. The major benefits of reinforced sand are:

- The inclusion of reinforcement in sand improves the shear resistance of the sand thereby improving its structural capability.
- The inclusion of reinforcement enables the use of poorer quality sands to be used as structural components.
- Land acquisition can be kept to a minimum because reinforced structures can be made steeper than would otherwise be possible.
- Construction time can be reduced when reinforced sand techniques are used.

### 2.1.3 Methods [8]

- Mechanical method of Reinforcement:

  In this procedure, sands of different gradations are mixed together to obtain the desired property in the sand. This may be done at the site or at some other place from where it can be transported easily. The final mixture is then compacted by the usual methods to get the required density.

- Additive method of Reinforcement

  It refers to the addition of manufactured products into the sand, which in proper quantities enhances the quality of the sand. Materials such as cement, lime, bitumen, fly ash etc. are used as chemical additives. Sometimes different fibers are also used as reinforcements in the sand. The addition of these fibers takes place by two methods;

  a) Oriented fiber reinforcement-

  The fibers are arranged in some order and all the fibers are placed in the same orientation. The fibers are laid layer by layer in this type of orientation. Continuous fibers in the form of sheets, strips or bars etc. are used systematically in this type of arrangement.

  b) Random fiber reinforcement-

  This arrangement has discrete fibers distributed randomly in the sand mass. The mixing is done until the sand and the reinforcement form a more or less homogeneous mixture. Materials used in this type of reinforcements are generally derived from paper, nylon, metals or other materials having varied physical properties.

Randomly distributed fibers have some advantages over the systematically distributed fibers. Somehow this way of reinforcement is similar to addition of admixtures such as cement, lime etc. Besides being easy to add and mix, this method also offers strength isotropy, decreases chance of potential weak planes which occur in the other case and provides ductility to the sand.

## 2.2 **Sand properties**

### 2.2.1 Volume Relationships

1) Void Ratio:

It is defined as the ratioof the volume of voids to the volume of solids. It is denoted by *e.* thus $e = V_v/V_s$.

2) Porosity:

It is defined as the ratio of the volume of voids to the total volume. Porossity is denoted by *n*.Thus $n=V_v/V$

3) Degree of Saturation:

It is defined as the volume of water to the volume of voids. It is denoted by S. thus $S=V_w/V_v$.

4) Realationship between porosity and void ratio:

$e= V_v/V_s= V_v/(V-V_v) =(V_v/V)/1- (V_v/V)$

$=n/(1-n)$

5)Dry unit weight:

It is defined as the weight of soil solids per unit volume. It is denoted by $\Upsilon_d$.

$\Upsilon_d= W_s/V$

### 2.2.2 Specific gravity

Specific gravity of a substance denotes the number of times that substance is heavier than water. In simpler words we can define it as the ratio between the mass of any substance of a definite volume divided by mass of equal volume of water. In case of soils, specific gravity is the number of times the soil solids are heavier than equal volume of water. Different types of soil have different specific gravities, general range for specific gravity of soils:

| | |
|---|---|
| Sand | 2.63-2.67 |
| Silt | 2.65-2.7 |
| Clay and Silty clay | 2.67-2.9 |
| Organic soil | <2.0 |

Table- 1

### 2.2.3 Shear strength

Shearing stresses are induced in a loaded sand and when these stresses reach their ultimate value, deformation starts in the sand which leads to failure of the sand mass. The shear strength of a sand is its resistance to the deformation caused by the shear stresses acting on the loaded sand. The shear strength of a sand is one of the most important characteristics. The Direct Shear Test method is generally used to determine the shear strength of sand at different relative densities. The shear resistance offered is made up of three parts:

i) The structural resistance to the sand displacement caused due to the sand particles getting interlocked,

ii) The frictional resistance at the contact point of various particles, and

iii) Cohesion or adhesion between the surface of the particles.

In case of cohesionless soils,like sand, the shear strength is entirely dependent upon the frictional resistance, while in others it comes from the internal friction as well as the cohesion.

Methods for measuring shear strength:

a) Direct Shear Test (DST)

This is the most common test used to determine the shear strength of the sand. In this experiment the sand is put inside a shear box closed from all sides and force is applied from one side until the sand fails. The shear stress is calculated by dividing this force with the area of the sand mass. This test can be performed in three conditions- undrained, drained and consolidated undrained depending upon the setup of the experiment.

# CHAPTER-3

# EXPERIMENTAL INVESTIGATIONS

**3.1** The experimental work consists of the following steps:

1. Specific gravity of sand
2. Determination of sand properties
   i) Maximum void Ratio( $e_{max}$)
   ii) Minimum Void Ratio( $e_{min}$)
3. Determination of Minimum dry density of sand($\Upsilon d$ min)
4. Determination of the maximum dry density of sand ($\Upsilon d$ max) by the use of the vibrating table and a hammer of weight 22kgs.
5. Preparation of reinforced soil samples.
6. Determination of cohesion (c)
7. Determination of angle of internal friction (Φ)
8. Determination of C and Φ by the use of

   i)Direct shear test

## 3.2 Brief steps involved in the experiments

### 3.2.1 Specific gravity of the sand

The specific gravity of soil is the ratio between the weight of the soil solids and weight of equal volume of water. It is measured by the help of a volumetric flask in a very simple experimental setup where the volume of the soil is found out and its weight is divided by the weight of equal volume of water.

$$\text{Specific Gravity } G = \frac{W_s}{W_w}$$

$W_w$- Mass of equal vol. of water as the soil solids.

$W_s$- Mass of Dry soil.

$W_2$- Mass of flask + Sand + Water filled to mark

$W$- Mass of Flask

$W_1$-Mass of flask +Water filled to mark

$W_w = (W_1 + W_s) - W_2$

Specific gravity is always measured in room temperature and reported to the nearest 0.1.

### 3.2.2 Procedure for the determination of minimum dry density of sand

Sand containing particles smaller than 9.50 mm should be placed as loosely as possible in the mould by pouring the sand through the spout in a steady stream. The spout should be adjusted so that the height of free fall of the sand is always 25 mm. While pouring the sand the pouring device should be moved in a spiral motion from the outside towards the centre to form a sand layer of uniform thickness without segregation. The mould should be filled approximately 25 mm above the top and levelled with top by. making one continuous pass with the steel straightedge. If all excess matter is not removed, an additional continuous pass should be made. Great care shall be exercised to avoid jarring the mould during the entire pouring and trimming operation. The mould and the sand should be weighed and the mass recorded.

### 3.2.3 Procedure of finding the maximum dry density of sand

The guide sleeve should be assembled on top of the mould and the clamp assemblies tightened so that the inner surfaces of the walls of the mould and the sleeve are in line. The lock nuts on the two set screws equipped with them should be tightened. The third clamp should be loosened, the guide sleeve removed, the empty mould weighed and its mass recorded. The mould should then be filled with the thoroughly mixed. The mould filled for the determination of minimum density may also be used for this test.The guide sleeves should be attached to the mould and the surcharge base plate should be placed on the sand surface. The surcharge weight should then be lowered on the base-plate using the hoist in the case of the 15 000 cm* mould.The mould should be fixed to the vibrator deck (see Fig. 1D for assembly. The vibrator control should be set at maximum amplitude and the loaded sand specimen should be vibrated for 8 minutes.

**FIG 1.D. THE VIBRATING TABLE ALONG WITH THE HAMMER**

### 3.2.4 Direct shear test

This test is used to find out the cohesion (c) and the angle of internal friction (φ) of the sand, these are the soil shear strength parameters. The shear strength is one of the most important soil properties and it is required whenever any structure depends on the soil shearing resistance. The test is conducted by putting the sand inside the shear box which is made up of two independent parts. A constant normal load (ς) is applied to obtain one value of c and φ. Horizontal load (shearing load) is increased at a constant rate and is applied till the failure point is reached. This load when divided with the area gives the shear strength 'τ' for that particular normal load. The equation goes as follows:

$$\tau = c + \sigma * \tan(\phi)$$

After repeating the experiment for different normal loads (ς) we obtain a plot which is a straight line with slope equal to angle of internal friction (φ) and intercept equal to the cohesion (c). Direct shear test is the easiest and the quickest way to determine the shear strength parameters of a soil sample. The preparation of the sample is also very easy in this experiment.

### 3.2.5 Determination of bearing capacity of sand using footing load test machine

Footing load test was performed to determine the ultimate bearing capacity of the sand sample. A cylindrical vessel with 40 depth and 44.2 cm diameter is used. The sand samples were prepared at different maximum dry densities. Then the samples were placed over the testing machine and the dial gauge and proving ring reading were noted down.From the above data graph was plotted between bearing pressure and settlement. The proving ring constant was found out to be 6.66N whereas the least count of the dial gauge for measuring the settlement was 0.01 mm.The proving ring had a loading capacity of 5kN and the rate of loading was 1.25mm/min.

**FIG 1.A- THE FOOTING LOAD TEST MACHINE**

**FIG- 1.B- SETTLEMENT OF RING FOOTING OVER SAND**

**FIG.1.C- BEHAVIOUR OF RING FOOTING OVER REINFORCED SAND**

# CHAPTER- 4

# RESULTS & DISCUSSIONS

### 4.0 Specific Gravity

| Description | Test 1 | Test 2 | Test 3 | Mean |
|---|---|---|---|---|
| W1(gms) | 356.1 | 361.8 | 368.4 | |
| W2(gms) | 426.5 | 423.6 | 430 | |
| Ws(gms) | 100 | 100 | 100 | |
| Ww(gms) | 38.6 | 38.8 | 38.4 | |
| W(gms) | 116.5 | 113 | 119.5 | |
| Gs | 2.59 | 2.58 | 2.6 | 2.59 |

Table no. 1 Take Gs = 2.59

### 4.0.1 Finding out the minimum dry density of sand

Diameter of mould=12.6cm

Depth =10cm

Volume of mould=989.6cm$^2$

| Experiment No. | Weight of sand (kg) | ϒdmin |
|---|---|---|
| 1 | 1.43 | 1.445 |
| 2 | 1.489 | 1.5 |
| 3 | 1.456 | 1.47 |

Take ϒdmin=1.445 Table no. 2

### 4.0.2 Finding out the maximum dry density of sand

Depth of mould used=16.5cm

Diameter of mould=15cm

Vol. of mould =Π/4d$^2$h=2915.79cm$^2$

| Experiment No. | Weight of sand (kg) | ϒdmax |
|---|---|---|
| 1 | 4.732 | 1.6228 |
| 2 | 4.749 | 1.628 |
| 3 | 4.736 | 1.621 |

Take ϒdmax=1.62 Table no. 3

### 4.1 Direct Shear Test

#### 4.1.1 For a sand of relative density 0.3

| Experiment No. | Normal Stress($kg/cm^2$) | Shear Stress($kg/cm^2$) |
|---|---|---|
| 1 | 0.5 | 0.363 |
| 2 | 1 | 0.7625 |
| 3 | 1.5 | 1.089 |
| 4 | 2 | 1.453 |

Table no.4

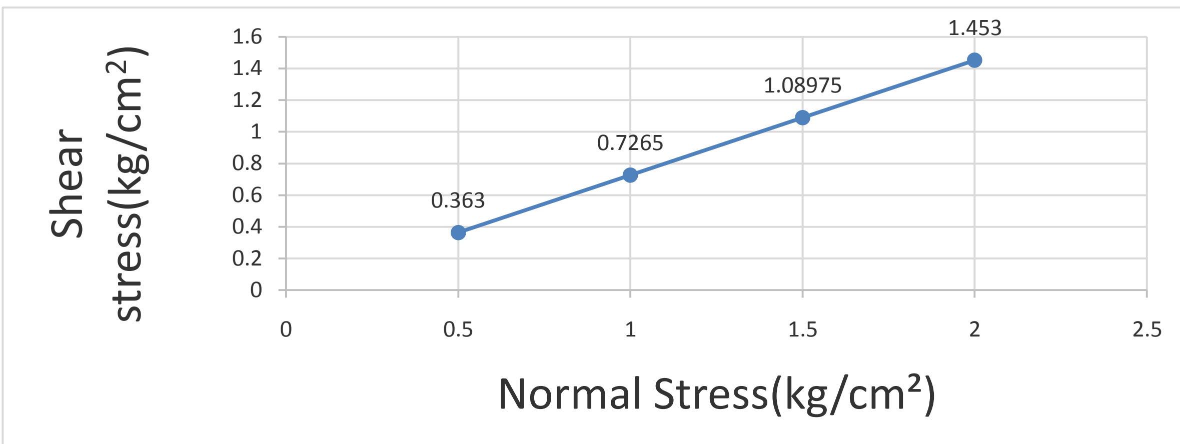


Figure no.1

The value of internal angle of friction as found out to be 36° from the figure 1 for sand of relative density 0.3

### 4.1.2 For a sand of relative density 0.6

| Experiment No. | Normal Stress($kg/cm^2$) | Shear Stress($kg/cm^2$) |
|---|---|---|
| 1 | 0.5 | 0.365 |
| 2 | 1 | 0.731 |
| 3 | 1.5 | 1.103 |
| 4 | 2 | 1.47 |

Table no.5

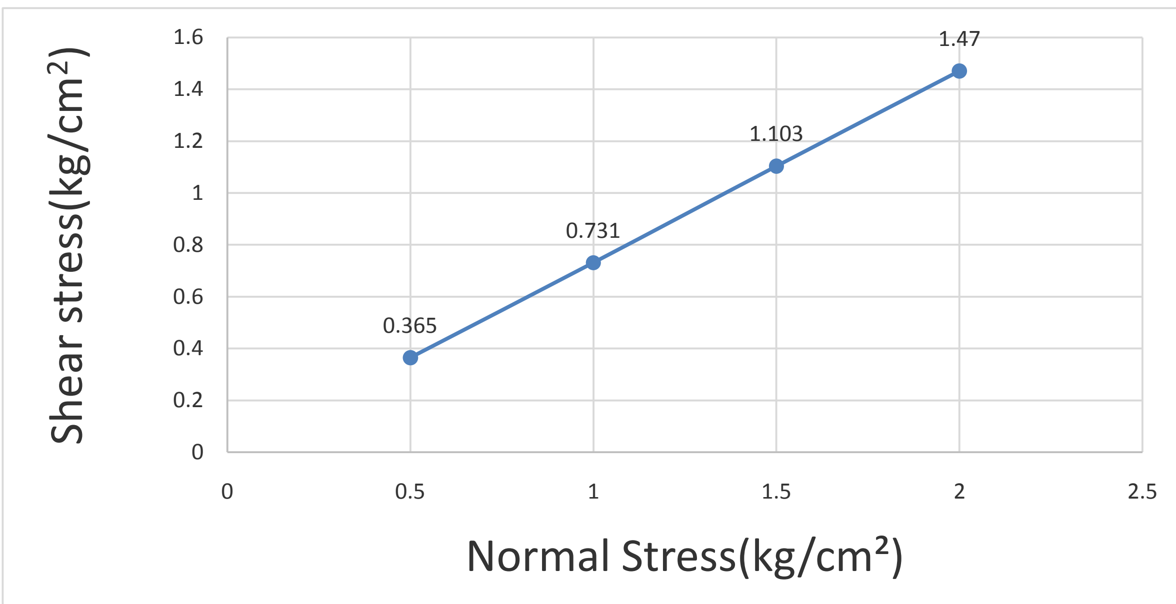


Figure 2

The value of internal angle of friction as found out to be 36.16° from the figure 1 for sand of relative density 0.6

### 4.1.3 For a sand of relative density 0.75

| Experiment No. | Normal Stress(kg/cm²) | Shear Stress(kg/cm$^2$) |
|---|---|---|
| 1 | 0.5 | 0.3767 |
| 2 | 1 | 0.7535 |
| 3 | 1.5 | 1.13025 |

Table no 6

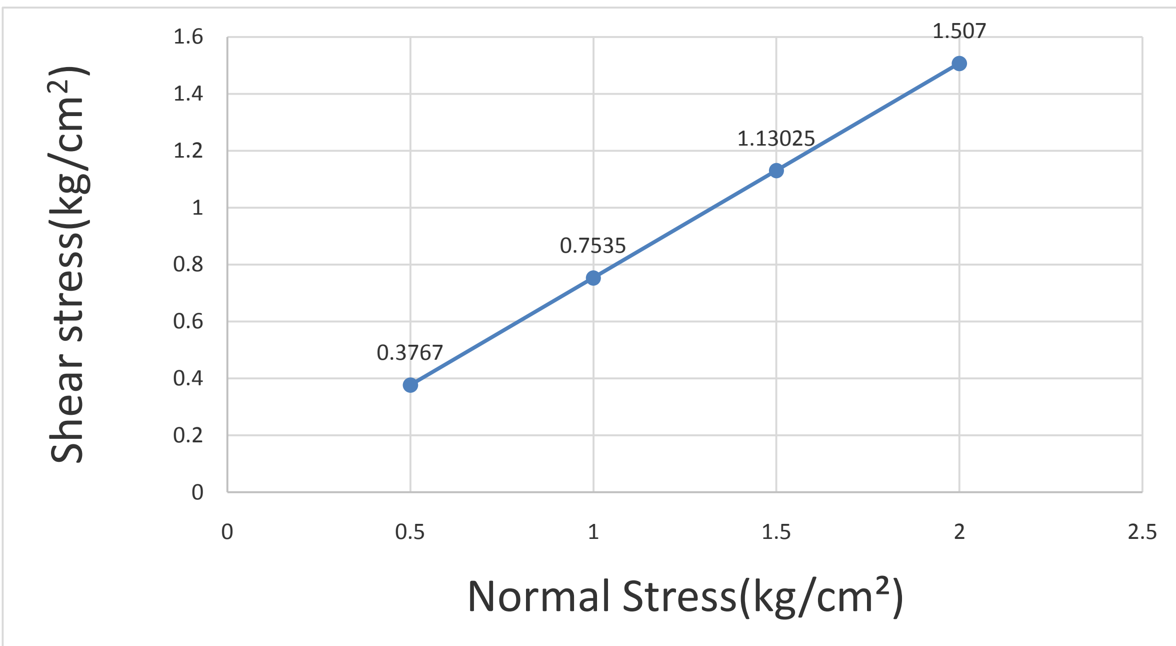


Figure3

The value of internal angle of friction as found out to be 37° from the figure 1 for sand of relative density 0.75

### 4.1.4 For a sand of relative density 0.9

| Experiment No. | Normal Stress($kg/cm^2$) | Shear Stress($kg/cm^2$) |
|---|---|---|
| 1 | 0.5 | 0.39 |
| 2 | 1 | 0.78 |
| 3 | 1.5 | 1.17 |

Table no 7

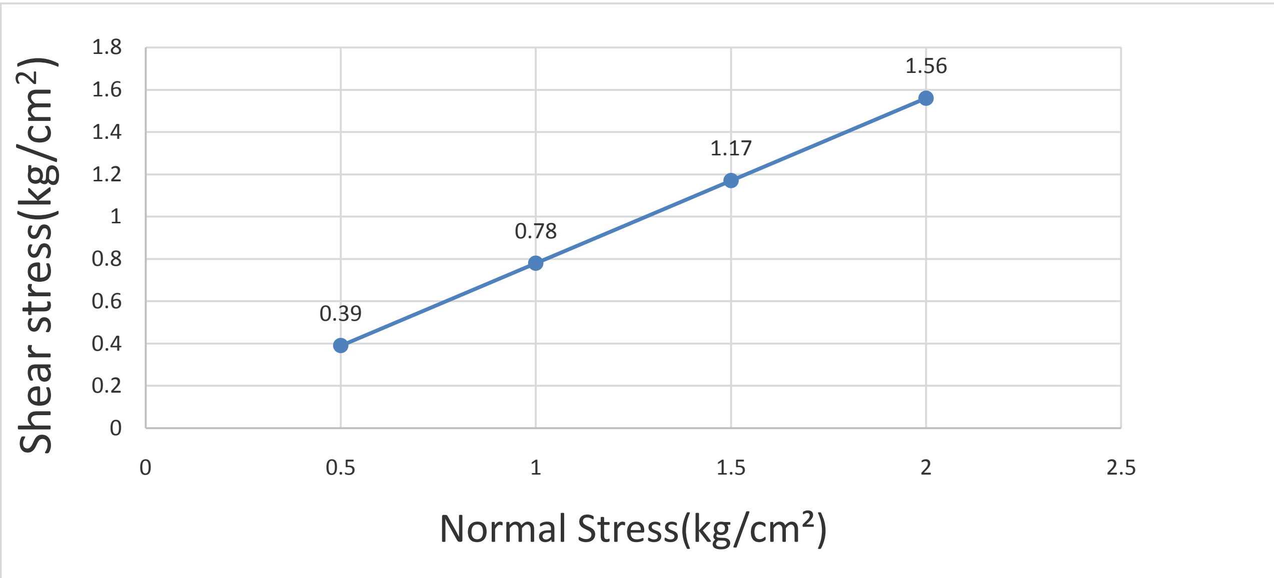


Figure 4

The value of internal angle of friction as found out to be 38° from the figure 1 for sand of relative density 0.9

### 4.2.1 Variation of the angle of internal friction with relative density of sand

| Relative Density(RD) | Coefficient Of friction Φ |
|---|---|
| | |
| 30 | 36° |
| 60 | 36.16° |
| 70 | 37° |
| 90 | 38° |

Table no 8

## 4.3.Bearing capacity of sand at different relative densities

### For a relative density of 0.3

| SETTLEMENT(mm) | PRESSURE(KN/m²) |
|---|---|
| 0 | 0 |
| 0.5 | 29.9 |
| 1 | 45.2 |
| 1.5 | 59.2 |
| 2 | 69.6 |
| 2.5 | 75.2 |
| 3 | 77.3 |
| 3.5 | 64.9 |
| 4 | 64.7 |
| 4.5 | 52.9 |
| 5 | 49.4 |

Table no 9

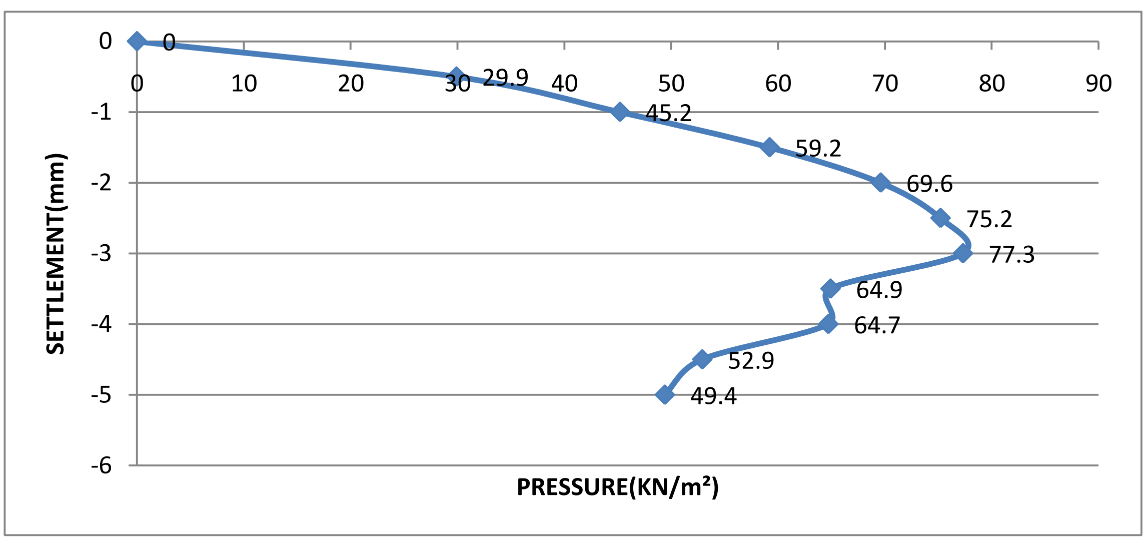


Figure no 5

The maximum bearing capacity of sand at relative density of 0.3 was found out to be 77.3KN/M2.

## For a sand of relative density 0.6

| SETTLEMENT(mm) | PRESSURE(KN/m²) |
|---|---|
| 0 | 0 |
| 0.5 | 37.6 |
| 1 | 71.7 |
| 1.5 | 104.4 |
| 2 | 130.2 |
| 2.5 | 142.7 |
| 3 | 135.0 |
| 3.5 | 111.4 |
| 4 | 89.1 |
| 4.5 | 72.4 |
| 5 | 62.6 |
| 5.5 | 52.4 |

Table no 10

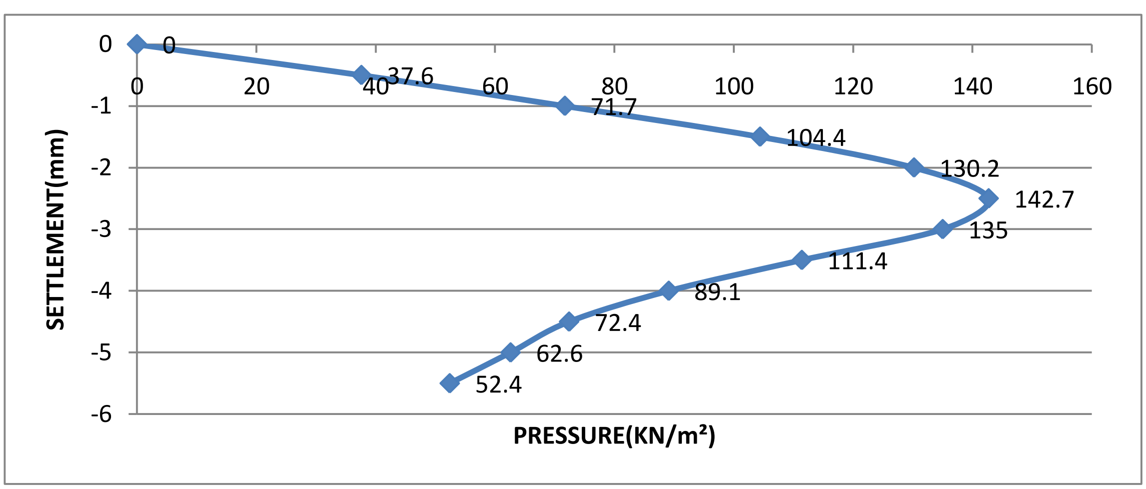


Figure no 6

The maximum bearing capacity of sand at relative density of 0.6 was found out to be 142.7KN/M2.

## For a sand of relative density 0.75

| SETTLEMENT(mm) | PRESSURE(KN/m²) |
|---|---|
| 0 | 0 |
| 0.5 | 48.1 |
| 1 | 92.6 |
| 1.5 | 152.3 |
| 2 | 197.6 |
| 2.5 | 253.6 |
| 3 | 227.4 |
| 3.5 | 181.2 |
| 4 | 142.1 |
| 4.5 | 103.7 |
| 5 | 72.3 |

Table no 11

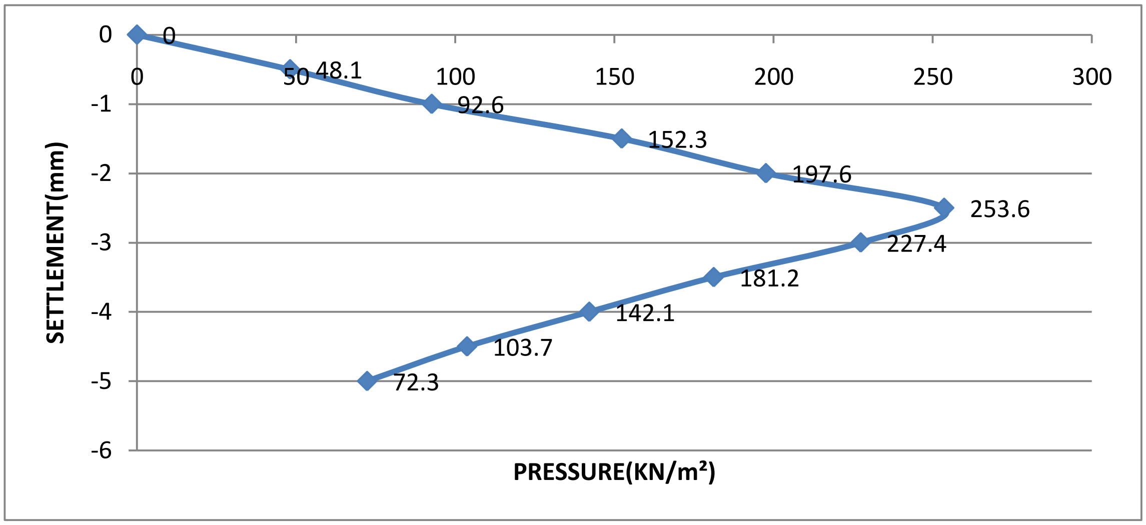


Figure no 7

The maximum bearing capacity of sand at relative density of 0.75 was found out to be 253.6KN/M2.

## 4.4.Bearing capacity of reinforced sand at relative density of 0.75 at different depths from the top of the sand layer

### 4.4.2 Reinforcement provided at a depth of 0.5 B

### Where B =outer diameter of ring footing

| SETTLEMENT(mm) | PRESSURE(KN/m$^2$) |
|---|---|
| 0 | 0 |
| 0.5 | 37.14 |
| 1 | 87.36 |
| 1.5 | 133.12 |
| 2 | 183.04 |
| 2.5 | 232.96 |
| 3 | 270.4 |
| 3.5 | 287 |
| 4 | 299.52 |
| 4.5 | 262.08 |
| 5 | 208 |
| 5.5 | 174.7 |

Table no 12

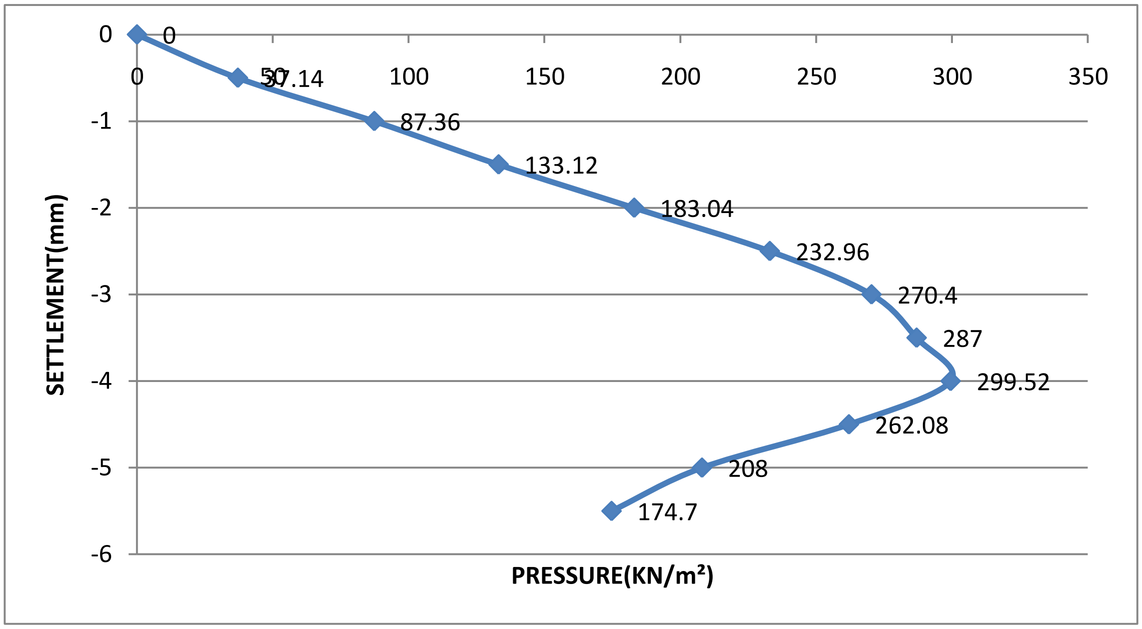


Figure no 8

The maximum bearing capacity of sand at relative density of 0.75 was found out to be 299.52KN/M2 at a depth of 0.5B.

### 4.4.3 Reinforcement provided at a depth of B

### Where B =outer diameter of ring footing

| SETTLEMENT(mm) | PRESSURE(KN/m²) |
|---|---|
| 0 | 0 |
| 0.5 | 51.74 |
| 1 | 108.16 |
| 1.5 | 166.4 |
| 2 | 220.48 |
| 2.5 | 262.08 |
| 3 | 295.36 |
| 3.5 | 312.0 |
| 4 | 287.04 |
| 4.5 | 212.16 |

Table no 13

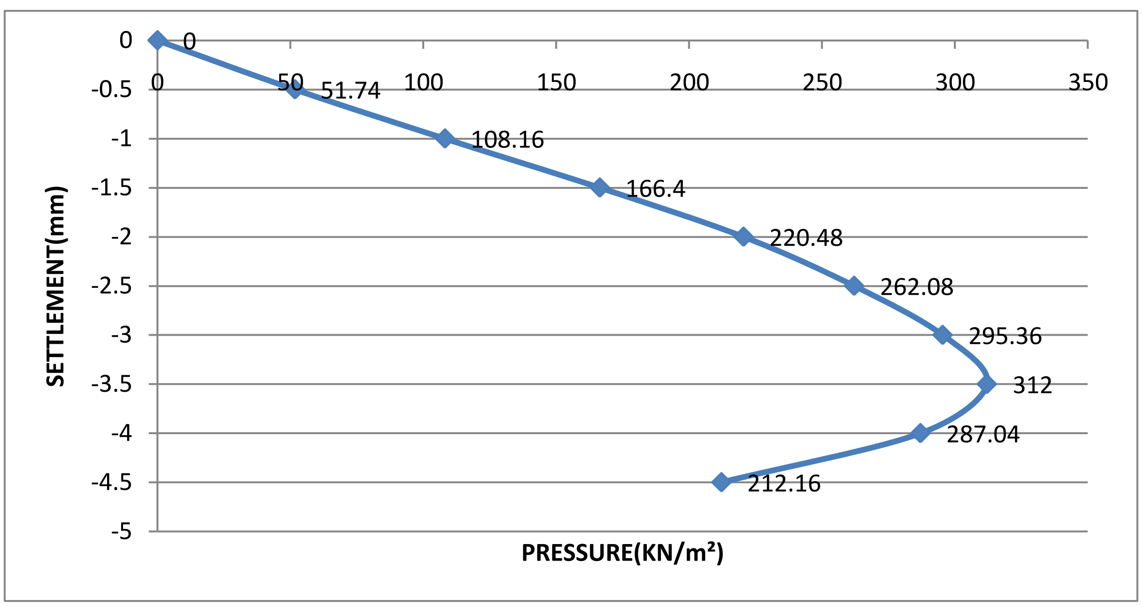


Figure no 9

The maximum bearing capacity of sand at relative density of 0.75 was found out to be 312KN/M2 at a depth of B.

## 4.4.4 Reinforcement provided at a depth of 1.5B

## Where B =outer diameter of ring footing

| SETTLEMENT(mm) | PRESSURE(KN/m$^2$) |
|---|---|
| 0 | 0 |
| 0.5 | 55.46 |
| 1 | 116.84 |
| 1.5 | 175.2 |
| 2 | 224.56 |
| 2.5 | 272.37 |
| 3 | 242.12 |
| 3.5 | 202.4 |
| 4 | 167.89 |
| 4.5 | 123.4 |
| 5 | 87.43 |

Table no 14

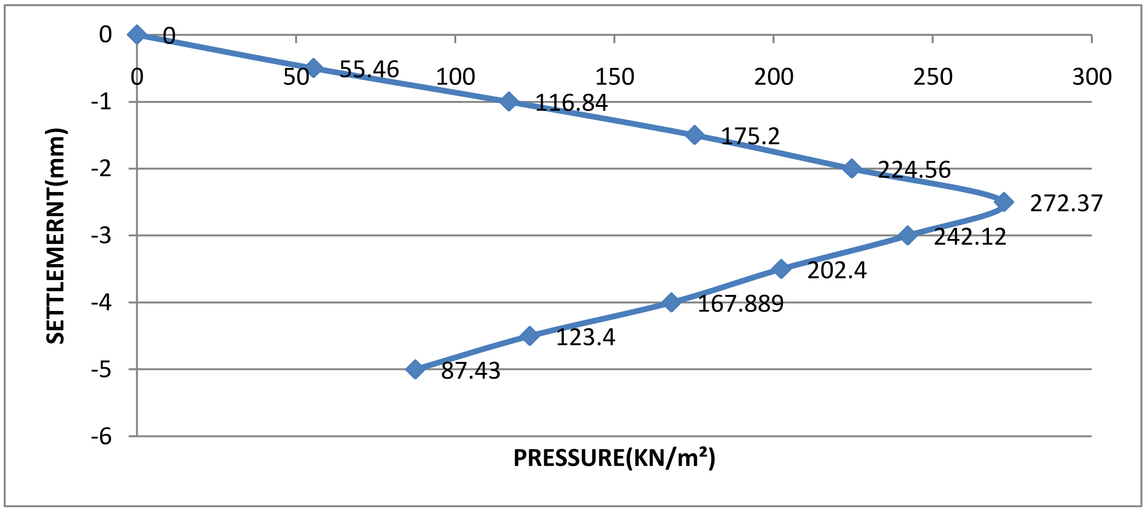


Figure no 10

The maximum bearing capacity of sand at relative density of 0.75 was found out to be 272.37KN/M2 at a depth of 1.5B.

### 4.4.5 Reinforcement provided at a depth of 2B

### Where B =outer diameter of ring footing

| SETTLEMENT(mm) | PRESSURE(KN/m²) |
|---|---|
| 0 | 0 |
| 0.5 | 52.8 |
| 1 | 103.4 |
| 1.5 | 147.8 |
| 2 | 202.3 |
| 2.5 | 261.8 |
| 3 | 230.1 |
| 3.5 | 193.2 |
| 4 | 152.9 |
| 4.5 | 114.5 |
| 5 | 82.1 |

Table no 15

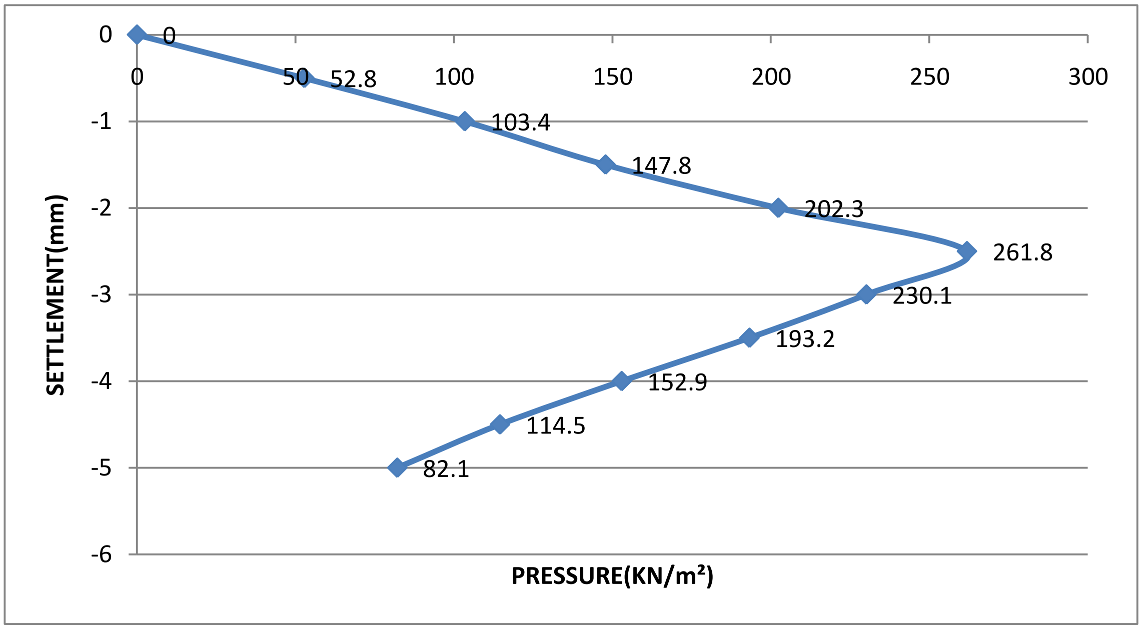


Figure no 11

The maximum bearing capacity of sand at relative density of 0.75 was found out to be 261.8KN/M2 at a depth of 2B.

# CONCLUSIONS

# CONCLUSIONS

On the basis of present experimental study, the following conclusions are drawn:

1. The maximum and minimum dry density of sand was found out to be 1.62kg/m3 and 1.445 kg/m3 respectively based on which the maximum and minimum void ratio of the unreinforced sand sample was found out to be 0.89 and 0.59 respectively.
2. The specific gravity of the sand sample was found out to be 2.59
3. On the results of the Direct test conducted over the sand sample the values of cohension © was found out to be zero. Thus concluding that sand is cohensionless in nature. The angle of internal friction (Φ) for sand samples of relative densities 0.3, 0.6, 0.75, 0.9 was found out to be 36°, 36.16°, 37°, 38°s respectively. Thus concluding that the value the angle of internal friction increases with the increase in the relative density of sand.
4. The maximum bearing capacity of the unreinforced sand sample for a relative density of 0.3, 0.6 and 0.75 was found out be 77.3kN/M2, 135.0kN/M2, 253.6kN/M2 respectively. Thus concluding from the above results that the maximum bearing capacity of sand increases with the increase in its relative density.

5. After reinforcement with the use of geosynthetics the maximum bearing capacity of sand for a relative density of 0.75 was found to increase considerably upto a depth of B, where B is the outer diameter of the ring footing. On the other hand its value decreased when reinforcement was provided below a depth of B from the top of the sand layer at a depth of 1.5B and 2B respectively.

5. The value of maximum bearing capacity of sand for a relative density of 0.75 increased at a depth of 0.5B and B by 18.10% i.e by 45.92kN/M2 and by 23.02% i.e by 54.8kN/M2 respectively .This increase in bearing capacity decreased to 7.4% i.e to 18.77kN/M2 and 3.2% i.e to 8.2kN/M2 at a depth of 1.5B and 2B respectively.

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